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CONTENTS

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AIR CONTROL APPARATUS

Paper presented to the Institution, Yorkshire Section, by Bernard C. Oldham

Introduction.

IN approaching the theme of air control apparatus it is essential to realise that the object is the control of air and not the instruments which control the apparatus for that purpose. Air is a wonderful substance ; though we are in intimate contact with it all our lives, we realise more and more as time goes on that we know very little about it. Yet there is hardly any phase of human activity or inactivity, or any industrial process, which is not in some way affected by the temperature, humidity, cleanliness as to dust and microbes, movement or some other conditions of the ambient air. The air we breathe has an important bearing on our health and activity ; indeed it has been said to mould the temper and genius of various human races. The English climate with its everchanging weather has played no small part in developing a physique which enables tropical and arctic regions alike to be successfully withstood ; and again, even without racial intermingling, new hereditary characteristics have been developed in British communities overseas, due principally to change of environment in which air is a leading factor.

Yet it is only within recent years that air engineering has come to the fore. In earlier days the freshness of uncontrolled country air was in strange contrast with indoor conditions, even in country dwellings. The regulations of the old craft guilds, though in advance of their time, paid little heed to air conditions ; even at the beginning of the seventeenth century Sir Francis Bacon, though an original thinker on many subjects, reflected the then popular belief that air was inimical to human welfare. " The exclusion of the *aire ambient* tendeth to lengthen life ; the body closeth up and not perspiring by the pores, detained the Spirit within." For town dwellers in the middle ages some excuse may be made for horror of outdoor air ; we know from records of frequent plagues, due to filth, that there was absence of organised sanitation and scavenging. This would account for the closing of windows to keep out foul odours and other noxious impurities.

Earlier Factory Conditions.

With the industrial revolution of the early part of the last century the substitution of the factory system for the small workshop

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meant much more than the substitution for hand labour of machinery and labour-saving equipment for all purposes. It introduced new problems of organisation for continuous supplies of materials in suitable conditions for the manufacturing processes; the drying, humidifying, heating, or cooling of both solids and liquids had to be accelerated or retarded in different manners and in larger quantities and the skill—that was almost instinct—of the individual craftsman who had previously carried out the whole of the operations was no longer available. Other problems may be instanced, such as that of heat generated by powerful machines destroying the passive state of air towards textiles or other moisture-containing materials, in contradistinction to the heat generated by the craftsman using hand or foot-power; dust collection and removal also became a health problem in the avoidance of industrial diseases.

Half a century ago the universal method of ventilation was to open doors and windows, or merely to rely on the air infiltration induced by the open fire. Gradually controlled ventilation became the rule, with mechanical ventilation comprising fans and ducts in the larger buildings, arranged for introduction of fresh air or for extraction of vitiated air or vapour. Then air purification by filtration and washing was developed for luxury buildings and is now popular with large department stores. It is gradually penetrating industries where hygiene is of paramount importance.

Conditions To-day.

Dust extraction is now almost a fine art, and with scientific combustion in large factories and powerhouses, together with the wide use of electric power, air pollution by industries is greatly minimised. With suitable air control the conditions in large factories can be as healthy as in any outdoor occupation. Improved factory conditions combined with improved sanitation and social services, and reduction in smoke from houses as well as factories, have been important factors in elevating the standard of health of urban populations far above the level which prevailed when the country was mainly rural.

Air movement in warehouses varies in importance with the goods in store. With some goods it is undesirable, with others it enables uniform conditions to be maintained. In conjunction with humidity control it reduces moulds and also infestation by insect pests in goods of plant origin such as tobacco, nuts, and dried fruits. Control of air temperature, hitherto an act of grace on the part of employers or of negotiations between employers and employees is now compulsory under the 1937 Factories Act, which also legislates for adequate ventilation.

Simultaneous and automatic control of air introduction, freeing

it from dust and odours, blending with recirculated air, humidifying or dehumidifying according to season, attemperating and distributing it in optimum conditions, is carried out in air conditioning, and any process which does not fulfil all these functions cannot correctly be known by that term. Unfortunately, many forms of apparatus

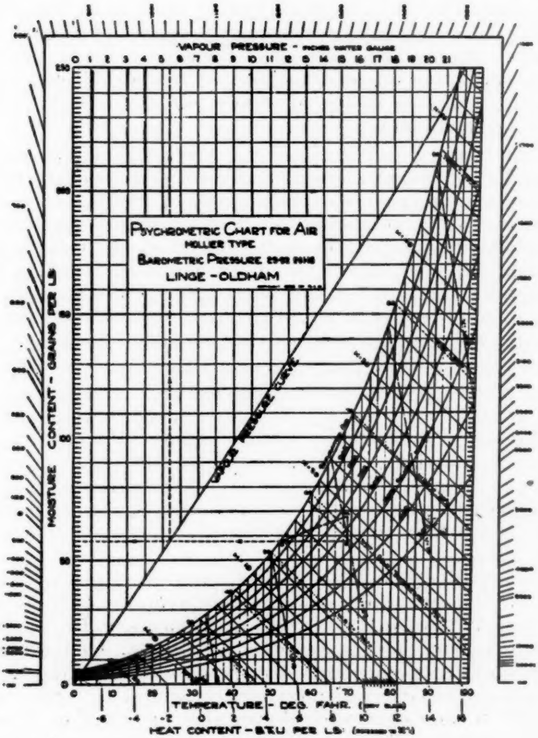

Fig. 1.—Psychrometric chart.

which merely combine air movement with one other function, however imperfectly controlled, are known as air conditioners. This term is very misleading.

Air Conditioning.

Air conditioning is taking a leading place. By its aid the factory manager may be assured of a consistent product, increased efficiency

among employees, and a happy dwindling of absentees through sickness. In the large department stores it is found that the better atmosphere inevitably induces a greater patronage, with fuller sales to customers who shop in greater comfort and swell the profits. In addition to this the spoilage of stock-in-trade is lessened. In the office, air conditioning brings an increase of personal energy, efficiency, and harmony, and in all cases a clean, pure, congenial air furnishes those conditions which cannot fail to " make the wheels go round." In the home also relief from hay fever and asthma is obtained and other obscure troubles of allergic subjects have been traced to impurities in the air which are removed by correctly applied air conditioning.

Air, like water, is so ubiquitous that one seldom stops to consider the manifold uses and abuses to which it is subjected. Probably nothing is more indicative of the progress of civilisation ; certainly nothing (not even important buildings or beauty spots) is more characteristic of a district, or more traded upon by holiday resorts. The conditions of the air, i.e., the weather and the wind are blamed for many ills, and credited with some cures. Their vagaries are an eternal topic of conversation ; the forces controlling them appear so remote that they are considered to be out of control.

When harnessed to industry air may be employed : (1) As the working fluid in internal combustion engines, whose power depends on the weight of air taken in ; (2) as a tool, e.g., in pneumatic tools or fluid-operated controllers ; (3) as a vehicle for transport of dust or granular materials ; (4) as a vehicle of comfort or of optimum process condition ; (5) in a compression type refrigerating machine, or (6) liquefied and a constituent gas removed, such as oxygen for welding and cutting, nitrogen for fertiliser, or argon and neon for electric lamps.

Air is a physical, not a chemical, mixture of gases, and when free of water vapour and carbon dioxide comprises 21% by volume of oxygen, 78% of nitrogen, with approximately 1% of the rare gases argon, neon, helium, krypton, and xenon. Of the latter the quantities of all except argon may be described as traces. Argon is the gas employed in gas-filled electric lamps, the name of neon is familiar in connection with electric signs, and helium in connection with airships. The remaining two gases, which comprise only one-millionth of the total also have characteristics suitable for electric lamps.

Other gases, such as CO_2 from respiration and motor car exhausts (the latter also contain CO carbon monoxide) and dust are impurities. Water vapour to some extent is beneficial ; when it is in excess it is either the result of a drying process or an impurity. CO_2 is normally between 0.03 and 0.07%, water vapour is .004 maximum by weight at 32°F., 0.016 maximum by weight when satu-

rated at 70°F., 0.03 at 90°F. saturated, and above that the proportion of water vapour to air rapidly increases. The convention is to speak of and calculate upon mixtures of air and water vapour in terms of heat, etc., per unit weight of air, not in weight of the mixture. This is to avoid a continually shifting basis of calculation. In a drying process, for instance, both weight and volume of mixture change continuously, but the weight of the air is constant. The size or speed of fan needed for a given duty thus depends on the volume of the mixture at the selected point in the air circuit.

The capacity of air to hold moisture also varies with the barometric pressure ; charts and tables are usually based on 29.92 in. (760 mm.) of mercury. With lower barometric pressures more moisture is carried for the same relative humidity ; this is also true for higher altitudes. With higher barometric pressures and in mines the capacity to contain moisture is less. In mines the net depression relative to sea level should be taken into account. The heat quantities involved in a simple heating process is a function of the specific heating of the air and its accompanying moisture in cooling and drying processes, latent heat as well as specific heat is involved, In drying, the rate of heating and air movement must harmonise with the diffusion of moisture in the material to avoid a case hardening effect which would hinder drying.

Air Movement.

The movement of air and gases when not under control depends upon differences in barometric pressure, just as in the genesis of winds ; the tendency to equalise pressure causes air to move from one spot to another. Chimney action or draught is engendered by differences of pressure as derived from density of efficient gases in comparison with that of the ambient air. An analogy may be made by considering a V-tube of the same height as the chimney with air at ambient temperature in one leg and the efficient gases at the working temperature in the other.

Heat recovery is often employed to economise in process costs by heat exchange, reducing the temperature and density of the effluent gases and at the same time preheating for another part of the process. In other cases a limitation of chimney height is desirable for constructional reasons.

To meet these needs and to control the rate of effluence the extractor diffusor has been developed. The design illustrated in Fig. 2 incorporates a fan of acial flow high efficiency type with blades and hub cast in high grade aluminium alloy in one piece in order to be suitable for fumes and high temperature gases. The blades are of aerofoil section and constant geometrical pitch to attain low power consumption. To render the motor independent of the nature of the gases handled it is located on the outside of the unit and the method of drive is worthy of note.

The object of the diffusion is the conversion of velocity head into pressure head, or static pressure regain. By the Bernouilli theory of conservation of energy of fluids in motion, the total energy at various sections in series is constant, except for the losses which occur between them. The components are kinetic energy or dynamic head represented by $v^2/_{2g}$ and potential energy or static head, $h \times P/\rho$, where h is the height factor relatively unimportant in

Fig. 2.—Extractor diffusors, with fan unit alongside.

air control, and P/ρ is the pressure exerted in all directions, i.e., bursting pressure, divided by density. Where density and height factor unchanged as in the short length of these diffusors the components are simplified to $v^2/_{2g}$ and P, and increase in cross sectional area reduced the velocity v and increases the static pressure P. The transformation is most efficient where the angle of the diffusor is between 3° and 10°. Velocity head is a

function of the kinetic energy equation $v^2/_{2g}$, the primary calculation being in feet of air column. This being an unstable value due to varying temperature and moisture control, and therefore varying density of air or gases, the conventional method is to express the head in inches of water gauge, the height of air column being converted into height of equivalent water column by dividing by the density of water relative to air. In practice the pressure is measured directly in height of water column by means of glass U-tubes. Static pressure, velocity pressure, and total pressure can be all read in this manner by arranging connection to U-tubes in various ways.

Fans.

The application of fans may be classed under the headings of ventilation, boiler mechanical draught, industrial, and dust handling The construction varies in each case according to the pressure and the degree of silence required, the nature and temperature of the air of gas handled, and the operating characteristics desired.

For duties involving low pressures and comparatively large volumes propeller and axial flow fans give superior performance to any other type; small space requirements also combined with simplicity of arrangement and erection. The simplest form of propeller fan is one in which the propeller is mounted on the spindle of an electric motor carried in arms supported from a ring frame. The latter is bolted to a wall or partition and forms the porthole airway. One type has a streamlined hub the function of which is to improve efficiency by avoiding eddies. Other types of propeller fans are the box blade now nearly obsolete and the axial flow. Some are made to propel air equally well in both directions according to direction of rotation of the motor. Several methods of driving are available to suit conditions at site.

Centrifugal fans are in the majority of instances housed in sheet metal or cast iron casings, and are alternatively termed "cased" fans. Where employed without casing the efficiency is naturally low owing to absence of directional control at discharge, less effective conversion of velocity into pressure and short circuiting between discharge and suction. The operating characteristics of centrifugal fans depend principally on the shape of the blades of the impellers or runners. The main types are forward curved, backward curved, and radial.

The forward curved type, besides having its blades curved forward in the direction of the rotation is also characterised by a larger number of blades than others, and is alternatively termed "multi-vane." It is capable of handling large volumes of air at medium peripheral speed and for a given duty has a smaller casing than other types. The quiet running characteristics of the medium peripheral

speed are largely negatived by a small discharge outlet, which entails high air speeds. It is liable to surging if not carefully selected, and power consumption rises rather steeply with low air pressures.

The backward curved type covers a wider range of performance at higher efficiency than other types and the power absorbed reaches a maximum at constant speed after which it commences to fall with increase in volume and drop in pressure. This power limiting characteristic is a valuable feature as it enables the motor rating to be near to the working power consumption and with higher power factor and efficiency.

Radial bladed fans have the characteristic of a small number of blades of appreciable depth ; these naturally have poorer characteristics and larger casing for some duty than the other types. They are partially useful for dust handling and transport of chips as the absence of curvature prevents clogging up.

Sheet metal casing of welded construction with angle iron stiffeners, pressed steel blades riveted to side plates, and steel fabricated inlet cones are fairly standard form of construction. Various methods of drive are available, driving by belt being useful to avoid motor noises being transmitted to the air stream and at the same time permitting a wide range of speed selection with motors of lower price due to ability to run at higher speed. In small centrifugal fans where silence is not important the motors are sometimes mounted by flange direct on the side of the fan casing. Provision for easy removal of the impeller with a minimum disturbance of joints and without disturbing the duct system is a valuable feature in some designs. Accurate balancing of impellers both statically and dynamically is of great importance. Fans for boiler house and for dust handling are of heavier construction than those for ventilating duties, in order to withstand abrasive dust.

The removal of dust in workshops is also increasingly engaging the attention of manufacturers who take an interest in cleanliness and efficient appearance, and of all who have a danger of silicosis. In many instances the removal of dust and chips, for example from woodworking machinery, is a necessity to secure the maximum production of which the modern high speed machines are capable. In addition the operator himself works more accurately and with greater speed when he has not to concern himself with cleaning his machine, and if he is working in surroundings of clean and orderly appearance. The ideal dust exhausting system is designed and installed in conjunction with the ventilating or conditioning scheme to ensure a balanced system, thus ensuring healthy atmospheric and temperature conditions in the factory, which is a big factor in maintaining maximum output from the staff.

The efficient operation of an exhausting system depends to a large extent on careful design of hoods for each particular machine and

accurate proportioning of ductwork to each machine, the velocity of air being so adjusted that it is sufficient to remove all dust and chippings, at the same time the volume of air handled must be kept to a minimum in view of the fact that the exhauster fan H.P. rises steeply in proportion to the volume of air handled.

Types of Collector and Fan Equipment

The requirements for a cyclone type collector are that its " resistance " or " pressure drop " should be as low as possible (the fan horse power being considerably affected by increase of collector resistance) and its collecting efficiency should be high enough to ensure that the amount of very fine dust escaping to atmosphere would not be sufficient to be noticeable or objectionable to neighbouring property-owners.

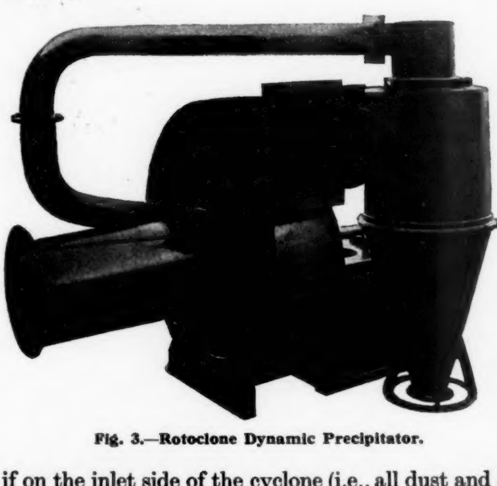

Fig. 3.—Rotoclone Dynamic Precipitator.

Fans, if on the inlet side of the cyclone (i.e., all dust and chippings passing through the fan) must be of the " non-choking " design, heavily constructed in steel plate and with substantial bearings and shaft. The single inlet non-choking fan with unshrouded impeller is most suitable if large splinters or chips or linty substances may be passed through the system. As an alternative where the factory layout permits, the exhauster fan may be placed on the outlet side of the collector and a cyclone of the " closed " type used. With this arrangement a different design of high efficiency fan may be used and substantial reductions made in the running cost of the apparatus due to the reduced fan horse-power.

Fig. 3 shows a unique unit known as the " Rotoclone " which

combines the duties of fan and cyclone and takes up little more space than an ordinary fan. It exhausts from the machines, or other sources of dust through hoods and ductwork in the usual way and discharges the dust to any required point, and the cleaned air through another discharge flange to any suitable outlet. It is

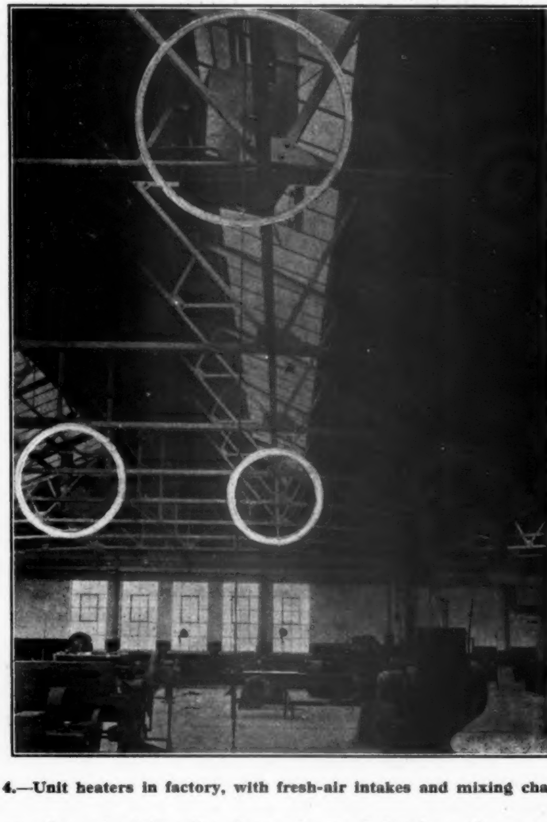

Fig. 4.—Unit heaters in factory, with fresh-air intakes and mixing chambers.

built on the principle of a dynamic precipitation, the actual precipitation taking place on the blades of an impeller, which is constructed similar in some ways to the impeller of a centrifugal fan, but with blades of specially heavy section and at a special angle and curvative.

A dynamic precipitation of the Rotoclone type will collect over 60% of dust 20 microns (.02 mm.) diameter. Where finer dust is involved the washer filter is applicable. In this apparatus suction is created by a fan and a wave is created, and all gases drawn through are impinged upon a wall of liquid, then washed by intimate contact with the spray. It is claimed that dust no larger than 0.2 inches microns has been found on microslide.

For the control of air température gilled tube air heater batteries or some other form of extended surface are made. The object of the extended surface is to increase the thermal conductivity from metal to air to approximately that of steam or hot water to metal. Air heaters of similar type but smaller, are embodied in the suspension type unit heaters of Fig. 4 and in wall type unit heaters. Those in Fig. 4 are arranged with mixing chambers and fresh air inlets, the latter taking in fresh air from the room, and the proportion of fresh and recirculated air is blended in the mixing chamber. Directional louvres throw the air downwards, the fan being of the propeller type. In the wall type the unit is fixed on a factory wall, and the fan is of the centrifugal type to give high capacity and long throw from the high velocity outlets. Fittings can be provided for handling fresh air only, or forming fresh air and recirculated air proportional at will. Distribution ducting can also be fitted on the discharge side when the layout requires it.

In this country central heating has not made the same progress as in some other countries : the ordinary central heating installation does not meet the real needs of the British. Most of us have a dislike for the conditions produced by central heating without perhaps knowing the reason why. With a central heating installation an extremely dry atmosphere is produced forming a great contrast with the relative humidity of the outside atmosphere to which we in this country are accustomed. These very conditions are not good for the sensitive membranes of the nose and throat which cannot adjust themselves so rapidly to the contrasting conditions ; the result is that we experience a sense of stuffiness and become prone to colds and headaches.

Another trouble which arises from central heating is that we never have it warm enough. This may sound paradoxical but it is actually the case, as the rate of evaporation from the pores of the skin is considerably increased in the dry atmosphere with a result that a sense of chilliness is produced. In buildings equipped with correct air control, these disadvantages are eliminated and a comfortable and healthy humidity is maintained all the time. Among the other advantages may be mentioned the complete elimination of fog and the prevention of dirt and dust, as all air movement in the rooms is outwards, exfiltration taking the place of infiltration. The condition that is normal to the fireside is avoided, viz., warming

the air at the point it leaves the room, with radiated heat on one side only while the back and feet are chilled by cold draughts from window and doors. Central air conditioning enables every part of a room to be occupied in comfort instead of only at the fireside. A winter air conditioning assembly for a private residence can be suitable for placing in the roof space or attic for supplying fresh air at correct

Fig. 5.—Central Air Conditioner.

temperature to some or all of the rooms. Fig. 5 shows an air-conditioning plant for large residences and offices. There are also air-conditioners for complete winter and summer air conditioning, incorporating refrigeration and combining filtration, automatic tempering, dehumidifying, or humidifying according to season, and scientific distribution, all within fine limits.

Where possible it is an advantage to incorporate an air distribution system in the general architecture of a building ; it can then be made unobtrusive and fit in with the aesthetic characteristics ; space can be utilised and laid out to the best advantage. The type of heating or cooling and the alternative of complete air conditioning system should be carefully considered from the beginning and the results taken into account in conjunction with first cost. The latter should not be the governing factor. Improved health, increased efficiency, greater energy, minimising of traffic noises, absence of draughts and dust, evenness of temperature quickly enable the additional cost of air conditioning to be recouped. In factories regular production, irrespective of weather, often demands air conditioning ; the finest chocolates can be completely spoilt in a few minutes of heat wave conditions. Skill in design is essential to ensure that air conditioning balances requirements. In the case of dehumidification the concomitant cooling is most consistently carried out by direct contract with water in an air washer ; one actually dries air by wetting it, but at scientifically selected temperatures.

An alternative method is extended surface coolers which usually employ the direct expansion method in which the cooling fluid is a refrigerant evaporating under the control of a compressor which is automatically started and stopped within preset temperature or pressure ranges. Whichever method is employed the factor determining the condensing out of moisture is the partial pressure of aqueous vapour in the air leaving the washer, and this in turn depends upon the temperature and nature of the cooling surface whether water, brine, ice, or a film of water on metal.

Humidifiers

Humidity, or incorrect degree of humidity, with or without dust, can make or mar innumerable products, whether grain in store, tobacco, textiles, timber, or steel tools or fine mechanical parts. On days of high humidity one has only to touch steel instruments or parts or to allow warm moist air to pass over them and within a few minutes rust commences to form ; a little rust on thin sensitive bars can do irreparable harm. Dust on such parts is difficult and expensive to remove ; prevention is not only better than cure, but the latter is often impossible. Microphone discs and razor blades are examples of parts which are subjected to cold dry air between 10° F. and minus 10° C., at which the moisture content is only $^{1}/_{12}$ of that at 85° F., and 65% relative humidity. Packing under this condition and bringing up to ordinary temperatures in airtight containers removes any fear of rust. For the calibration of instruments whose delicacy and sensitivity is of paramount importance, too great care of air conditions cannot be taken and the safety of life in the air may depend thereon.

Materials of organic origin, such as textiles, tobacco, and paper require humidity to be kept at a level higher than that of the ambient air, and for these humidifying heating and ventilating units are made. (Fig. 6).

Humidifying must not be confused with a Turkish bath atmosphere or even a fog. It is the control of the invisible water content of air by a very small but important percentage. Multicolour printing, for example, relies on absence of stretch or contraction of paper

Fig. 6.—Hygrotemper Humidifier.

between various printing operations to avoid overlapping and misplacing of colours. It is therefore essential for the air of the pressroom to be in hygroscopic equilibrium with the paper.

In textile manufacturing processes the control of humidity is essential to ensure consistency of handling conditions, weight, and size ; absence of brittleness, and removal of danger from static electricity. The tobacco trade, with its discriminating public demanding consistency of quality, improved flavour, and aroma, whether in tobacco, cigar, or cigarette, requires the control of

humidity combined with temperature in all stages of manufacture. With its aid quality is not only improved, but waste is minimised, enabling important manufacturing economies to be made. Incorrect physical conditions of the leaf jeopardise the uniformity of operations. Too big a moisture content causes a tendency in cigarettes to become lumpy and " broken backs " ensue unless extreme care is taken, this entailing slowing manufacture. On the other hand too low a moisture content causes an increase in the precentage of unusable shorts and smalls.

The chemical constituents in the leaf are affected by the relation between air temperature humidity and air movement ; stabilisation of air conditions is also important for this reason to facilitate the diffusion of essential oils in blending, and correct evaporation of volatile constituents in the conditioning processes. The flavour and aroma of the finished product may be entirely changed in character according to skill or carelessness. Only by control of all aspects of every operation, particularly the condition of the atmosphere and the absence of zones of humid and dry air can the uniformity required for a recognised brand be obtained.

An important factor in humidity control is the hygroscopity or otherwise of the material involved. Although air at 70° F. cannot hold water to the extent of more than 1½% of its weight, wool at the same temperature can hold water to the extent of 33% of its own weight and cotton about half that amount. Paper too, can hold enormous quantities of water. A great deal therefore depends upon whether the material processed in a humidity controlled atmosphere is at the desired conditions prior to entering the process rooms, in which case only a passive condition need be allowed for, otherwise an interchange of moisture between air and goods termed hygroscopic regain, has to be calculated upon.

Atmospheric humidity affects the human body in three functions ; respiration, perspiration, and drying affect through the skin other than through the pores. The effect of air movement on comfort varies in hot climates according to whether the air temperature is below or above the body temperature. When below 98½° F. any air in excess of that required to evaporate perspiration cools the body still further by removing sensible heat ; when above 98½° F., it is important that the rate of air flow should not exceed its capacity for evaporating perspiration, or sensible heat will be added, causing discomfort and headaches.

List of Lantern Slides Used

1. Density of moist air.
2. Psychrometric chart. (Fig. 1 in paper).
3. Heat of cooling *vs.* heating.
4. Extractor diffusors. (Fig. 2 in paper).
5. Fan unit for ditto.
6. Static pressure regain.
7. Pressure diagram (efficiency).
8. Velocity head.
9. Propeller fan.
10. Centrifugal fan runners.
11. Supersilent centrifugal fans.
12. Rotoclone. (Fig. 3 in paper).
13. Washer filter.
14. Washer filter assembly.
15. Microslide showing dust extraction.
16. Unit cell air filter.
17. Gilled tube air heater.
18. Unit heater in factory. (Fig. 4 in paper).
19. Wall type unit heater.
20. Draughts.
21. Air conditioner (house).
22. ,, (residential and offices). (Fig. 5 in paper).
23. ,, (complete with refrigeration).
24. Vapour pressure.
25. Hygrotemper. (Fig. 6 in paper).
26. Wet and dry bulb readings.
27. Ducting arrangements.
28. ,, (bends and joints).
29. ,, (seams).
30. Ducts with twin branches.
31. Air washer under construction.
32. Air cooler casing.

For the Illustrations to this Paper acknowledgments are made to Messrs. Air Control Installations, Ltd.

INDUSTRIAL SAFETY

Paper presented to the Institution, London Section, by F. Southwell, M.I.P.E.

Introduction.

I WAS very glad to receive the invitation to read a paper upon this subject, because so many things vital to safety generally emanate from the production engineer. At the moment so many buildings, lay-outs, and processes are introduced in which little thought has been given to the safety and health of the worker. Then later when accidents or ill-health arise, or the factory inspector intervenes, safety devices, fans, guards, exits, etc., which should have been included in the planning arrangements have to be irregularly introduced. I also want to show how closely allied are economic production, with both the health and safety of the personnel generally. In brief I think that very much more can be done for safety by talking to the members of an Institution such as ours, than by Safety First Posters and slogans, or by a police court prosecution which quite often follows a breach of the Factories Act.

General.

Commencing with a measure called the Health and Morals of Apprentices Act, passed in 1802, factory legislation now exercises considerable influence over the conditions prevailing in industry to-day. The Act of 1802 referred to was passed to safeguard the women and children employed in the textile industry. Prior to its passing the conditions prevailing in this industry were very bad indeed. This Act was so successful that it was extended to cover other trades, with little or no opposition from employers, who found that it had been beneficial to their interests as well as to those whom they employed.

Many Acts have been passed since that date, culminating in the Factories Act of 1937, the arrival of which was long overdue, when one remembers that its predecessor was passed as long ago as 1901. Since 1901 industrial progress has been so rapid that the old Act was entirely out of date. The new Act, although it has, or will have, such far reaching effects, has been received in an extremely good spirit by industry as a whole and this is a sign of the times.

Generally speaking the conditions laid down in the 1937 Act represent the conditions prevailing in the best managed factories and its demands are therefore not expressions of pious hope, but in many cases of accomplished fact. That the Act has been so

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12 December, 1938.

well received is due chiefly to a new consciousness of the responsibilities of management towards their personnel as well as the realisation that safe and hygienic working conditions walk hand in hand with economic production.

It has always been my opinion that the late war had a considerable influence upon this matter, in many ways. The employment of women during that period in industries where only male labour had previously been used, called into being a Welfare Section of the Ministry of Munitions. This led to the introduction of works' surgeries, rest rooms, canteens, etc. Again, the utilisation of unskilled labour upon machinery, probably reasonably safe in skilled hands, but decidedly unsafe in unskilled hands, led to an appreciation of the need to guard certain parts of such machinery, because of the inability of the unskilled operator to appreciate the latent dangers prevailing. Further, I think executives, by virtue of the lack of skilled assistance, had to get more on top of their jobs than had been their wont. This made them appreciative of the lack of thought previously given to such things as hoists, runways, lighting, etc. They found, too, that men and women unused to the various tasks they were called upon to do, suffered from fatigue, eye strain, skin rashes, and many other things, any one of which was calculated to react against their ability to give of their best. So that when the various " aids " were provided, it became obvious to those in authority that by obviating the dangers to life and limb and improving the working conditions, they had not only performed humanitarian work, but had given a considerable boost to production.

These lessons were not forgotten by those who experienced them. I, for one, did not forget, and my post-war experience on production, and my more recent experience as a safety engineer, have confirmed the opinions formed then that safe and hygienic conditions have a high production value, and cannot be dissociated from production planning.

There is little virtue in purchasing a highly productive machine tool, if it is put where the operator's movements are restricted, or where he has to walk 20 yds. in order to get enough light to read his micrometer. Nor are you likely to get results if you put it into a foul atmosphere or in a shop where the operator is frozen in winter and baked in summer. In a similar manner jigs and fixtures are often designed in such a way that their operation brings an operator's hands in dangerous proximity to cutters. A milling jig, for instance, with a locking clamp or nut near the cutters which could, with the exercise of a little ingenuity, have been put in another position. The designer of such equipment should endeavour to put himself in the position of the operator, and appreciate the fact that accidents to operators, calling for a lay-off, or constant visits to the surgery,

are not without their cost—overheads maybe—but still costs. It is therefore very necessary that the production engineer should appreciate all these points if he is to get anything like full return from the capital invested in machinery and its equipment.

Buildings.

If a new building is projected, a very good chance of starting right from all points of view is available. The architect, if he has experience of industrial buildings, should be quite competent to look after the requirements of the Factories Act, local bye laws affecting sanitary and fire arrangements. Nevertheless, the submission of any plans to a competent safety engineer will save a lot of trouble later. In the case of fire arrangements, I would suggest that they come within the building planning and not just "added" willy-nilly afterwards. I would also earnestly suggest that some thought be given to the cleaning of windows, and here again, safety and economy combine.

If buildings exist, and a reorganisation is pending, advantage should be taken to bring it in line with the Act's requirement as to space, ventilation, etc. There are, I know, concerns not too prosperous who will not entertain expenditure for improvements in working conditions. They may say that what spare capital they have, is required for additional plant, which they probably propose to pack into an already overcrowded shop. This is a short-sighted policy for it is bound to increase production costs, and will most certainly increase the risk of accidents.

Housekeeping.

Whatever the process, and whatever the working conditions, it is essential both as regards safety and efficiency that attention is given to this most important question. There can be nothing so detrimental to life and limb as blocked gangways, piles of junk, dirty windows and lamps, oily or worn floors, etc. A factory or a department may be cramped for room, and if that is so then tidiness and orderliness become of still greater importance. Clean lamps, floors, and windows, well marked gangways, apart from efficiency safety and work quality, are bound to have a psychological effect upon the minds of the operators which in turn is bound to improve their health and mental outlook and make them both better citizens and operators.

Lighting.

This matter, except in the larger plants, does not receive the prominence it deserves, again both as regards safety, health, and efficiency.

It is only during the relatively past few years that man has been called upon to work in artificial light. Throughout the ages he has

relied upon the sun, which gave him 10,000-ft. candles of light to play with—even in the shade of a tree he had about 1,500-ft. candles. Thus in a comparatively few years the human eye has had to accustom itself to fine work and to fine measurement for long periods, not in 10,000 but in probably something like 5-ft. candles. Can we wonder then that one-third of the population wear glasses, and goodness knows how many others ought to be doing so, or that operators suffer from headaches and nervous strain resulting from indifferent lighting. Such conditions tend to make the individual's perception slow and a ready victim to accident.

The speed with which the eye sees and the brain perceives is purely a matter of light, other things being equal. On a sunny day with a camera an instantaneous photograph can be taken successfully, whilst on a dull day one has to allow a few seconds exposure to get a photograph of equal quality. A similar thing applies with sight—the poorer the light the greater the time lag between the eye seeing and brain perceiving. This time lag can make all the difference between a safe step and a stumble, or the safe removal of what otherwise might have been a trapped finger.

In the same way a time lag between each phase of a machine operation does not make for speed. In a somewhat similar way that which applies to the lack of light also applies to glare and shadow. We all know what effect the glare of an approaching headlight is and how often it provokes an accident.

Glare can be the direct cause of accident in the shops in addition to causing eyestrain. Shadow in a machine shop—or anywhere, for that matter—is difficult to avoid, and accidents arising from the passage from brightness to shadow, or from an operator having to peer at his job because he is standing in his own light, are numerous.

A good general lighting scheme showing up gangways used, in conjunction with a local lighting scheme, is generally satisfactory, but poor general lighting where gangways, etc., are not well defined, and a good local lighting, can be bad from the stumbling and colliding accident point of view. If a shop is badly lighted from either of the causes mentioned, it is virtually manned with a crowd of shortsighted people who by stumbling and fumbling cannot produce efficiently, and are in constant danger of injury. Lighting, then, is of importance both from the accident prevention and the production points of view.

Heating and Ventilation.

These two functions are so closely allied to each other that I am taking them together. I can say without fear of contradiction, that if personnel are to work safely and efficiently, with due regard to their health, a plentiful supply of fresh air at a reasonable temperature is necessary. In a vitiated or stuffy atmosphere there is

lethargic tendency due to an increase of carbon dioxide and a corresponding reduction in oxygen. This lethargy or tiredness, reduces normal alertness and in so doing increases the risk of accident to those working under such conditions.

Bad lighting can produce a time lag between seeing and brain action. With a bad atmosphere we get a time lag brought about by an insufficiency of oxygenated blood circulating through the brain. This being so it does not require much imagination to see what could be the effect upon safety, on health, and on the efficiency of the personnel, in an area where both lighting and ventilating conditions are bad.

It is not within the scope of this paper to discuss ventilating systems except to say that there are many bad ones. Ventilation does not mean the promiscuous introduction of currents of cold air at high velocities as many people appear to think.

Generally speaking, a reasonably good scheme is the installation of fans drawing air from the outside—away from any sources of contamination—coupled with heaters (electrical, steam or high pressure hot water) through which can be drawn or discharged hot air in winter and cool air in summer. This scheme maintains a plenum inside the shop to the exclusion of draught.

The need for an efficient heating system, if safety, health and efficiency are to be safeguarded, will be readily admitted. The need for preserving the sensitivity, deftness and manipulative qualities of such important tools as fingers will be readily appreciated, by those who are interested in production. The loss of these qualities is definitely the cause of a very large number of accidents amongst machine operators and any who are engaged in the handling of material.

Such safe and efficient conditions cannot prevail in a shop with a temperature a few degrees above freezing point where one sees (and probably has had personal experience of) people " cluttered up " with clothing and scarves, ready to get hitched on any revolving tool shaft or gears. From both the safety and the efficiency points of view, one wants to see personnel operating, virtually in their vests, both in summer and winter alike, with no trailing appendages likely to cause accident, or restrict free movement.

There is one point which I have so far not raised in connection with this section and that is air-conditioning. This, I know, presents very great difficulties when one is considering factories in general. Air-conditioning concerns the cleansing, heating (or cooling) and the humidification of the atmosphere. If you have any doubt as to the need for cleansing I would ask you to inspect the intake duct or the radiator units of a ventilating fan. I am certain, that within the next decade or so, air conditioning will be standard practice in all well managed plants.

Accident Prevention.

The three foregoing sections have sought to deal with comfort and well-being of the workers, with the certain knowledge that in making working conditions as well as is possible, we shall be: (a) Preserving their health; (b) removing many primary causes of accidents; (c) ensuring that the physical execution of our production planning will be efficiently carried out.

Having done this we will now turn to the physical side of our safety problems. Here again, I can only generalise because of the complexity of modern industrial methods.

The new Factories Act demands that prime movers, transmissions, flywheels, etc., and all dangerous parts of machinery must be securely fenced, but where this is impossible certain automatic guards or devices may be employed. In other words any piece of machinery plant such as rotating stock bars, milling cutters, saws, spindle moulders, press tools, must be so designed or so guarded as to exclude the possibility of injury to anyone operating it or working in the vicinity. It also imposes upon the manufacturers or factor of plant and machinery the responsibility of protecting such machinery before sale. It further imposes upon those operating such plant the responsibility of using such protective appliances as are supplied. Nevertheless, it still leaves the user with the responsibilities for seeing that such things as gearing, flywheels, couplings, main driving, belts, chains, hoists, cranes, electrical gear, are rendered safe.

It must also be remembered that any belt or shaft (vertical, horizontal or oblique) is a dangerous part of a machine and as such must be protected; $\frac{1}{2}$ to $\frac{3}{4}$ in. wire mesh mounted on tubular frames either fixed to the machines or stepped into sockets let into the ground, form the best belt guards. On each we fix a brass notice bearing the plant No. and words "Replace Guard before starting work."

Regulation 641 permits certain certified people to approach unfenced machinery for the purpose of oiling, inspecting or testing. providing that such work is immediately necessary and *must be done* whilst the machinery is in motion, and that such person is wearing the Regulation one-piece overall and has been given a copy of the prescribed leaflet.

The normal overhead shafting form of transmission presents a serious problem. Thirty people are killed every year and some 1,500 others injured as the result of accidents arising from this source. A new Section (13) has been introduced into the Act, calling for every part of transmission machinery to be fenced unless it is in such a position or of such construction as to be safe for all people in the factory. It also makes it an offence to allow a belt to lie upon a revolving shaft—a very dangerous practice—and high

time official notice has been taken, for many a machine has been torn from its foundation and overturned on to its operator. Again, it calls for an easily accessible power control point enabling power to be cut off quickly, whilst appliances to prevent belt-creep must be fitted. In this respect although machines are motorised remote control is sometimes necessary within easy reach of the operator.

Usually shafting is safe by position until someone gets up a ladder or stands upon a box in order to oil the bearings or replace a belt. When this is done a " safe by position plea," should an accident occur, is sheer waste of time, in the subsequent police court proceedings. Suitable belt poles and a one shot lubrication system operatəd from the ground obviates either of these two risks.

Contractors' men are a nuisance in respect to shafting, live wiring, and similar normally "safe by position situations." Men engaged in painting up aloft, are liable to get mixed up with such dangers, and of course the occupier is held responsible. The risk taken by outside contractors' men became so great some time ago that we introduced : (*a*) A compensation clause in all our contracts ; (*b*) an abbreviated set of our safety regulations, which we sent with each order, and their fulfilment was a condition of that order or contract. One of the conditions is that the men in charge of any job had to call at my office before commencing work.

Power Presses—Small.

The guarding of press tools presents one of the biggest problems in my experience. In quoting the section of the Act dealing with dangerous machinery I was not quite correct. The Act says, in effect, that where a fixed guard cannot be used, a device which automatically prevents the operator from coming into contact with the danger, may be used.

It will be readily agreed that a fixed fence, which definitely excludes any part of the body from entering the danger area, is a perfect safeguard. In order to make use of fixed guards wherever possible, I designed a system of adjustable fixed guards, which by the manipulation of removable bars enable openings to be formed to suit various jobs.

Unfortunately, in most press work certainly in the motor trade, some 50% of the jobs handled call for the hand (or tongs) to be inserted between or adjacent to the tools. In this case some form of automatic guard has to be introduced. There are quite a number of automatic guards for small presses upon the market, which seek to remove the operator's hands or arms should he by inadvertence put in the clutch prior to withdrawing his hands, or alternatively should the press, due to a clutch or brake fault, make a " repeat " stroke. In one type the moving shield is interlocked with both the clutch pedal and the crankshaft. The first inch or so of the pedals—

depression shuts the swinging gate—totally enclosing the danger area. Further movement of the pedal puts in the clutch and as a result the ram descends.

Should the operator leave his hand behind, the swinging gate cannot close and further pedal depression is impossible and the clutch will not engage. In the event of a " repeat " stroke—that is when the pedal has not been depressed—then the rotating crank, operating through a linkage connected to the pedal control comes into action and starts to close the swinging gate. Should an arm or hand be between this gate and the bottom rail of the outside frame, the moving shield being immobilised, the movement is transferred to the whole outer frame, which swings rapidly out bringing the trapped arm with it and way from the danger zone.

There is also a similar guard having a vertical shutter in place of the swing-out one. This permits the use of a larger die, without calling for any outward adjustment. It is, however, more difficult to make, because the direct lift called for by the vertical shutter as opposed to swinging movement of the other type, calls for a lot of counter-balancing in order to ease the load which its weight imposes upon the pedal.

With this type of guard the shutter, either vertical or swinging, returns to normal as soon as the pressure upon the pedal is released. Therefore, in the case of a " stamp," e.g., quick depression of pedal and immediate removal of the foot, the shield or shutter is likely to be going back before the ram is down.

To overcome this the linkage engages with a cam lever and when the gate is shut a pin engages in a slot in this lever. The engagement of this holds the shield in the closed position until the cam lever is struck by a cam fixed to the revolving crank, and the pin is released allowing the ram and the shutter to return to their top position together.

Large Presses.

Large presses, say from 3 ft. to 15 ft. in width, are very difficult to guard. Generally speaking little or nothing has so far been done. Fixed guarding, by virtue of the size of the components handled, is practically out of the question, for the simple reason that, although it may be possible to insert a sheet in a die through a slot in a fixed guard you certainly would not be able to get it out through such a slot, when it has assumed the shape of a mudguard, and of course if your opening is large enough to allow of the mudguard being taken out, then an arm could also be put in.

Many forms of solenoid controls have been and are being used. Generally, this system provides a switch operating a solenoid for each operator. These switches are so positioned that each operator has to step back in order to reach it. Each solenoid is attached to some form or pawl or plunger, each of which are interlocked with

the clutch mechanism, and in such a way prevents clutch engagement, until all pins are withdrawn by the operation of all the switches. Similar devices are used on air operated clutch gear, where an air valve instead of a solenoid is fitted for each operator. In this case the non-opening of any one of the valves prevents the admission of air to the clutch control cylinder and the clutch cannot be engaged.

The Home Office do not favour these devices because they are: (*a*) Liable to interference; (*b*) do not give protection against "repeat" strokes, or in the event of a press running back.

Although heavy presses are comparatively slow in action, there have been a considerable number of accidents upon them, and they are therefore dangerous machines and as such the law demands that they should be securely fenced.

The Factory Department have recently formed a joint committee to consider the ways and means of bringing this about and I have the honour of serving upon this committee. Many attempts have been made to devise efficient guards, the bulk of which are still in their experimental stages. The majority of these also do not cope with the very large variety of jobs which any press may have to handle, and consequently would therefore only be in partial use. This would be a very unsatisfactory state to be in, because it would confuse the minds of the operators by (*a*) sometimes having no guard, (*b*) continually changing method of guarding.

We have designed a guard and have fitted all our larger presses with it, that is presses from 3 ft. to 15 ft. in width, to the total of some 65. This guard consists briefly of four standard units mounted on each column of the press—back and front—connected by simple levers to the ram. The levers are arranged to suit the stroke of the press, whatever that may be, in order that the bar will come out a standard distance.

Each pair of units are connected by a solid drawn tube, to the ends of these units, by a spring plunger fitting in a counter bored slot in the unit end. This allows of the complete and quick removal of the tube for die insertion or withdrawal without impedence. When the ram descends the bar is rapidly pushed out, around the operator's middle, and he is forced back, out of harm's way. The general arrangement of this guard with simple attachments permits any type of job to be handled and yet affords protection against the ram's fall, whether intentional or not, either backwards or forwards.

To overcome the tendency to lean over the bar or tube when loading a low loading job and thus run a risk of an operator pitching in, an attachment can be used, which incorporates a tilting bar, which would in such circumstances bring the operator back again. This is a recent addition and will ultimately be standardised.

I must apologise for spending so much time on this section but

I am sure you will agree that it is rather an important matter, inasmuch as whilst all press accidents result in mutilation of some sort, those on large presses often mean the loss of one or even two arms or hands. Again, little has been done in the guarding of heavy presses, and the factory department are getting impatient.

Woodworking Machinery.

Woodworking machinery is always a potential cause of accident and for that reason is the subject of special regulations. The danger in a large mill engaged upon mass production is usually less than in a small jobbing shop. The chief reason for this is due to the fact that with large batches going through more time can be economically spent on the knocking up of reasonably safe fencing than with the smaller batches in the smaller mills.

My experience with the highly dangerous spindle moulders is that a properly designed jig or holding fixture, with holding knobs away from the cutter, is usually much safer than a poorly made fence. Mass production of certain parts like the cant rails or door pillars of a motor body can be machined in the recently introduced automatically fed spindle moulder. The rough curved form of the component is obtained with the aid of a former and dished circular saw of small diameter; this is quicker and safer than the older method of marking-out and band sawing. The roughly formed piece is then fixed into a jig and is roller fed past a guarded cutter block, with both the operator and his taker-off well away from danger.

Strange to say, we had our only fatal saw mill accident in connection with this machine. In this case a component was flung out of the jig and by sheer bad luck struck a man 12 ft. away and smashed his thigh. The man was far from being strong and he died from general toxaemia. It was thought that the component—a door pillar—was put into the recessed jig with the edge that was taking the thrust broken off causing it to ride over the edge of the jig. We afterwards carried out experiments with similarly broken pillars, but did not succeed in getting one thrown back.

Circular saws, with properly adjusted guard and riving knife, and the enforced use of a push stick, can be reasonably safe. Many serious accidents occur with this tool due to " kick backs " and this type of accident is invariably due to an ineffective riving knife allowing the timber to bind on the back of the saw. These accidents often cause severe stomach injuries. Similar accidents can happen upon straight-edgers and planers, and it is our practice to equip our men with a stout leather apron to wear about their abdomen.

Just a point here which really concerns lighting, but which we have found of universal value. We paint all our woodworking machines a light cream which, with its high reflection factor, makes

the actual local lighting around the machine much better. This will be better appreciated when one realises that a battleship grey reflects but 11% of the light from a gas-filled lamp whereas pale cream reflects 76%.

Electrical Risks.

In spite of the tremendous increase in the consumption of electricity, the number of industrial accidents is remarkably low. The number of fatalities average about 30 annually. Generally speaking, both as regards personal safety and fire risk, it is very necessary to see that the electrical regulations are strictly adhered to, or that installation specifications call for the I.E.E. standards.

The chief dangers arise from the use of portable tools (including hand lamps) and the cause here, as in most electrical accidents, arise from faulty or non-existing earth connections. In addition, with portable tools heavy fuses have to be used, owing to constant stalling. Periodic examination of these tools should be enforced, in order to see that earth wires are unbroken. All our own electrical portable tools run on 110 volts and the connecting cables and plugs are in moulded rubber, the plugs and sockets being integral with the cable. Our portable and local lighting are 25 volts only.

There is a point worth mentioning in this connection which effects both safety and cost, where one has motorised machine tools, and desires to fit such machines with local lighting. In our case the power voltage to the driving motor is 440 volt A.C. and for our local lighting we introduce a 440 volt, 25 volt transformer (cost 30s.). This saves the cost of secondary lighting cable and conduit.

Overhead electrical cranes, taking the power from live trolley wires require careful watching, not only from your own repair point of view, but from outside painting contractors. Danger notices should be fixed at every 10 yds. or so. We use large stencils and paint on to the R.S.J. or walls. This method is much cheaper than enamel plates.

Where several cranes are on one track, one sometimes gets a breakdown on one, necessitating work going on near the live wires. To carry on both work and repair is desirable. Usually the power is cut off and a wooden fencing is built around the live wires, which takes some time, and then the power is switched on. To ensure that owing to the amount of work involved safety was not disregarded, I recently found a simpler way out. I got one of the rubber firms to make me 20 ft. lengths of split rubber tubing about $^3/_{16}$in. thick, the internal diameter being the same as the trolley wires. With the current off these lengths can be sprung over the wires in a few minutes, and in that way normal work can proceed in safety.

See that your steel ladders giving access to cranes are on the side away from the live wires. Another safety measure in this connec-

tion is worth mentioning. Trolley wires, especially if pure copper, quickly get a surface hardness, and then the usual surface cracks appear and there is a risk of fracture. A falling live wire will, of course, momentarily electrify anything with which it comes in contact, until the fuse goes. We fit a phase failure device at a cost of some £12 in each circuit. These devices, as you are probably aware, " cut out " as soon as the fracture occurs, so that the falling wire is dead before it starts to fall. Another point to remember with cranes, is to prohibit men from working on crane tracks. One of the most serious electrical risks usually met with is the too frequent use of temporary wiring.

A sudden need for additional lighting or power occurs and temporary wiring is often tacked on to a heavily loaded circuit, without any normal precautions, as to earthing, etc., and is usually trailed promiscuously over floors or machinery. I have often seen examples where an obliging electrician has run a temporary hand lead for use in a boiler carrying 220 volt A.C. In addition, unless a check is put upon these malpractices this temporary lighting will become permanent and sooner or later accident or fire results. We have evolved a set of temporary lighting instructions, which lays it down that the written consent of the chief electrician must be obtained for the running of any temporary cable. If he consents then tough rubber cable with an integral earth wire must be used, and periodic inspection has to be employed.

Fire Precautions.

The Factory Act lays down that a safety certificate must be obtained from the local authorities with respect to safe escape from fire, and heavy penalties may be incurred should a factory not be in possession of such a certificate. It is obviously better to prevent fires rather then to have them and efficiently extinguish them. In this respect education can play an important part in fire prevention and strong disciplinary action should be taken against those whose actions might start a fire.

I previously mentioned that good housekeeping played an important part in fire prevention, and I would like to stress this particular point again. Each industry possesses its own particular fire hazards. In a large motor car works there is such a variety of these that I will, with your permission, give a brief outline of our own fire arrangements.

We maintain a voluntary brigade of 40 men under a professional chief and first officer. Included in the above are 12 permanent firemen, who patrol all danger areas throughout the twenty-four hours. There are about 100 internal fire alarms with indicator panels in each area. In some 25 danger areas these alarms are coupled direct to the town brigade as well as our own. Throughout

the factory, at frequent intervals, are appropriate first-aid apparatus such as soda-acid foam (for oil), C.T.C. (for electrical fires), water and sand buckets.

A point worth noting here is that well up over each piece of apparatus a large red disc is painted on the wall, or R.S.J. as the case may be, and the type of apparatus is marked in white upon this disc, thus E—Electrical, F—Foam, S.A.—Soda-acid. This enables their positions to be seen from a distance and also designates the type. All buildings, inside and out, are plentifully supplied with hydrants, and a large white " H " upon a red disc indicates their positions. Water for all fire services is supplied by two artesian wells capable of supplying 80,000 gallons per hour.

Storage is effected by three large water tanks around the plant having a total capacity of 700,000 gallons. All buildings, other than pure machining areas, are equipped with automatic sprinklers. These are fed from a closed circuit and a pressure of 140 lb. is maintained by means of a 3,500 gallon air pressure tank. When a fire occurs and a sprinkler goes, a bell rings and the fire alarm system operates. When the pressure in the tank falls to 90 lb. turbine pumps come into action and maintain the correct pressure.

It is usual to fit long buildings at intervals with fire doors to prevent the spread of a fire. Most of our long buildings house our assembly tracks making it almost impossible to fit such doors. We have, after a lot of experimental work, overcome the difficulty by fitting double rows of drenchers, which are controlled by fusible links, or alternatively can be operated by hand. We are confident, therefore, that we can by this means prevent the spread of fire, without the fire door difficulties. There is another point with water curtains, escape made difficult by the premature closing of steel doors, does not arise.

One of our chief fire risks is, of course, in connection with cellulose, and here again after many practical experiments we have proved to our complete satisfaction that water, if finely atomised, will very effectively put out any cellulose fire. Therefore, all our spray booths have drenchers in the trunking, which by a series of fusible links around the sides of the booth, will operate automatically. Alternatively they can be hand-operated. The hand apparatus is run for five minutes after each shift to (a) check its efficiency; (b) to damp down the deposit of cellulose upon the sides of the trunking. Incidentally, reverting to fire prevention, these booths are cleaned out each Saturday to the satisfaction of the area fire officer, who makes out a report upon a prescribed form.

In the danger areas, adjacent to the main exits, are fire alarms linked to the town brigade, and master switches cutting off all power. Apart from cutting out any electrical risk, in the cellulose

area, for instance, there would be some 50 large suction fans at work which if left running would help the fire.

Another of our risks is connected with our enamel plants, where tanks holding many thousands of gallons of enamel are continually in use. Underneath the enamel are the heating units, burning fuel oil. These units are housed in fireproof cubicles with hollow steel sides and roof filled with asbestos. In a recent fire in a cubicle the whole heating unit, made from a fire-resisting alloy, melted away but the cubicle held the fire, and apart from stopping the enamel conveyors and emptying the enamel into their appropriate steel tanks, no harm was done.

The system we have adopted for dealing with an enamel fire entails the use of CO_2. Batteries of interconnected cylinders of this gas are connected to a net-work of drilled piping run over the surface of the enamel tanks and drip booths. The gas control valve is operated by the breaking down of a fusible link, and the gas would then smother the surface of the enamel with a blanket of CO_2. Prior to adopting CO_2 we had a foam plant which accidentally went off once and not only scrapped the enamel, but took many days to clear up the mess. CO_2 is quite harmless in this way.

Air Raid Precautions.

It would appear, in view of the prevailing unsettled political situation, that air raid precautions will become a permanent part of our national life. This being so, then industrial management has got to shoulder additional responsibilities.

If, as we are led to believe, this country in a future war will be in danger of intensive aerial bombardment, then steps have got to be taken by industry to (*a*) protect personnel; (*b*) protect its buildings and essential plant as far as is possible; (*c*) pursue its possibly vital production with the minimum waste of time

To ensure the safety of personnel and to maintain their morale, shelters giving a reasonable protection against the blast and fragmentations of high explosive, and fume and gas bombs, must be provided. It would clearly be wrong to (*a*) keep large numbers of people massed in vulnerable buildings, or (*b*) to disperse them into the streets where they would be in great danger from every form of aerial attack, as well as to seriously interfere with vital A.R.P. services.

Where there is no available land, suitable basements or semi basements should be selected and carefully planned arrangements drawn up for stiffening floors above to withstand the weight of falling debris, etc., which, if not put in hand at once, could be carried out expeditiously should an emergency arise. Large numbers of people in one building or basement should be avoided. Where large basements, etc., are capable of holding a large number, sub

division into smaller sections holding 50 people should be arranged, by walls of sand bags, etc. Complete dispersal plans should be designed, so that each individual knows exactly what he has to do and where he has to go.

The normal production executives from area managers to charge hands would be responsible for their respective charges. Other services such as fire, ambulance, essential services, etc., should be organised, trained, equipped, and housed, the whole to be co-ordinated and controlled by a controller. If land is available then suitable trenches should be constructed. The cost may appear high but they offer the maximum safety against blast and fragmentation, and reasonable protection against gas, whilst there is much less chance of a heavy death roll in the event of a direct hit, or near hit.

During a war there would be a large number of abortive warnings and if trenches or suitably strengthened shelters were arranged in buildings a lesser amount of time will be lost than would be the case with dispersal into the street.

That is all I have to say, and I trust that out of many words I have spoken I have at least been able to illustrate in a large number of cases how closely accident, sickness and fire prevention, apart from any humanitarian standpoint, are allied to economy of production.

Discussion.

MR. G. W. CLARKE : I wish to deal to-night with the question of guarding power presses, and fully agree with Mr. Southwell's remark that this presents one of the biggest problems of the whole series. The wording of the Act in connection with this particular problem may be construed in different ways by different inspectors and some of them have already intimated that automatic guards are entirely unacceptable. One can only agree with Mr. Southwell's dictum that a fixed fence is a perfect safeguard if one pre-supposes that the fixed fence is itself perfectly made and designed and is perfectly located and perfectly fixed. Any errors in the design of the fence or in its location and fixing may result in danger to the operator and if each tool is to have its own fixed guard, then the multiplication of such fixed guards which carry in themselves the chances of error must inevitably multiply the chances of accident either through wrong design of guards or wrong fixing of guards to the machines. In some factories where changes are infrequent and the machines run for long periods on one set-up, the problem is not difficult, but where the number of tools runs into many thousands and the presses are changed from job to job every few hours, the difficulties are enormously increased.

If one attempts to design efficient fixed guards for every one of the many tools, it would be entirely unreasonable to expect every one to be perfect in design and still less reasonable to expect that every one would be set up perfectly correctly through the rapid and frequent changes. Mr. Southwell has drawn attention to another danger and the point is, I think, a particularly good one, that continually changing methods of guarding must cause confusion in the minds of the operators and thereby increase the risk of accident.

I am quite sure that Mr. Southwell will agree with me that his adjustable fixed guards might be wrongly set and I can even imagine some of the bars becoming bent or missing, and if he should be called upon to set many presses twice or more every day with different jobs and tools, every time, he and all concerned would need to possess divine qualities in order to avoid a percentage of mistakes.

Because of these difficulties I feel that for conditions such as I have indicated, it is desirable that the guard should be part of the machine and should accommodate as many of the tools as possible. The construction and maintenance of such a guard will receive far more care and attention than can be given to each individual fixed guard among thousands and we have all experienced the almost uncanny certainty with which a wrong one, if such

exists, turns up at the crucial moment. A guard embodied in the machine can be strongly built, permanently fitted, and subject to constant inspection.

It is agreed that automatic guards as marketed have defects and may not be suitable for some work but my company, and doubtless others, have made very great efforts through modifications to perfect them and render them safe and suitable for the work. We found that guards as marketed were fitted with several adjustments. This is in itself is a danger because it permits *wrong* adjustment and, moreover, it was found that the settings tended to creep out of adjustment while the press was working. We, therefore, re-designed and re-constructed them, eliminated most of the moving parts and setting devices, and permanently fixed the mechanism in correct adjustment.

Through analysing an accident which occurred, we realised that the effective movement of the guard must take place through the first eighth of the crank revolution. The operating device was, therefore, changed to a carefully designed cam fitted directly on the press crankshaft engaging a loose hinged latch to work the gate when needed. By this means we were able to reduce the adjustments to one only—the gate opening, to swing the guard clear upwards for setting tools without disconnection or disturbance and to render the action entirely independent of the length of stroke.

On checking with friends in various parts of the country, I find that every district seems to have a different interpretation of the law on this matter. In the one place mechanical guards are acceptable and preferred, in another taboo, while others find both types acceptable and I have even heard of places, mostly small ones, where the factory inspector is himself a rarity. If I ask " What are we trying to do ? " the answer should surely be " To prevent accidents." I am very much afraid that in these circumstances our brains and energies are likely to be diverted from this objective and the cause of safety will suffer in consequence.

At the National Safety Conference last Easter I ventured to put a suggestion forward which was well received, and if you will permit me to encroach a little further on your time it will stand repeating. It is as follows : Everyone here knows that for a number of years past the Home Office have issued and maintained a series of regulations covering the industrial use of electrical appliances and these regulations apply not only to the installation and use of such equipment but include many exacting requirements respecting the design and performance of the apparatus. One has only to consult any catalogue of standard electrical equipment to note that makers invariably claim that their apparatus conforms to the Home Office regulations. It is interesting to note that these electrical regulations are very largely based on rules which were formulated by the

Institution of Electrical Engineers and do in fact represent the considered opinion of the electrical industry as to the proper means for ensuring safety in working. The conception and enforcement of these regulations has reacted upon the general design of electrical gear, with the result that it is almost impossible to buy standard equipment which does not embody proper safety features which are designed with and built into it.

The new Factory Act now empowers the Home Office to institute similar regulations covering the design, sale, and operation of machinery and, moreover, authorises them to prevent under heavy penalty the sale and use of equipment which does not embody efficient safeguards. This is a far reaching change and if sound judgment is used in formulating governing regulations, it may be safely assumed that the results will tend to match those resulting from the electrical regulations. In matters of safety and particularly where mechanical movements are concerned, there is often room for diversity in opinion, and it is here suggested that the formulation of standard rules might be a very valuable field of activity for this Institution, whose members spend their lives in closest contact with every phase of factory life. Such contact must imply close and expert acquaintance not only with its technical problems but also with the human factors involved.

The existing situation is unsatisfactory with engineers on the one hand seeking effective answers to a series of very difficult problems and on the other hand the factory inspectors each with his own interpretation of the law and generally adopting a negative attitude. In the result the engineer is left with a conviction that his constructive efforts are baulked and frustrated, and the inspectors are equally dissatisfied.

The National Safety First Association have done excellent work for the cause of safety in general and their work would be assisted by expert help on specific difficult problems such as this. The suggestion I have made does not mean that we should encroach upon the proper field of the Engineering Standards Institution in specifying precise details of a wide range of safeguards, but rather that we could render valuable aid in formulating operating rules on which such standards could be based. I have in mind that we might be able to draw up a safety code for operating power presses, with appropriate sections for light, medium, and heavy presses. Respecting such a question as automatic guards the rules would specify the conditions essential to safe working and might cover, for instance, permissible methods of mechanical operation, interlocking requirements, fixity of adjustments, frequency of inspection. Operating limits respecting : Timing, number of adjustment points, length of action, depth of hand space, speed of withdrawal, gate dimensions, side guard clearances. These few points occur to me and others

would doubtless arise as the scheme develops. Assuming that we could produce a satisfactory safety code for power press work, the system could be extended from time to time to cover other classes of machine operation, and I do submit in all sincerity that the Home Office would be well advised to take production engineers in general into consultation and that this Institution in particular could render service with credit to itself and to the general good of all engaged in the industry. The factory inspectors have no monopoly in their anxiety to secure safe working conditions, but neither have they a monopoly of the knowledge regarding the best guards to use in an infinite variety of circumstances.

Mr. F. Southwell: Mr. Clarke has made some very interesting additions to the subject about which we have been talking, and I agree with him to a very large degree that this Institution could do a great deal towards the drawing up of standards of safety. If one can get the production engineer to see these matters in the light that Mr. Clarke has just told us that he sees them, I am certain that 50% of their accident causations would disappear. And I think that some thought might be given to what Mr. Clarke has said with a view to combining with the Factory Department of the Home Office and offering help or advice: and I am certain that the Home Office would be very glad to receive such collaboration or any recommendations that the Institution would like to make.

There is a committee sitting whose aim is to try and poduce some specifications for guards that are going to be suitable for very large presses so that the men who work those presses shall receive a real margin of safety whilst they are operating. Of course it is very easy to touch on the fringes of some of these subjects, as Mr. Clarke would probably agree at once, and he himself has put in a lot of time trying to get some satisfactory guard which will protect the small presses. I can assure him that the problem of guarding heavy presses is a very much more involved one that that of small presses, when one considers the diversity of work that has got to be handled by the larger machines. But I do think that this press guarding committee which is now sitting have already made some wonderful advancement. Probably it has introduced a spirit of rivalry between various concerns and in that way has given a considerable fillip to the experimental work of these particular firms, and the result has been very satisfactory up to date. I can say with a good deal of certainty that probably within the next six months that committee will have some definite form of heavy press guarding to offer to the users of heavy presses.

Mr. Garrett: My first criticism—and Mr. Southwell will agree with me in this—is that he is a better engineer than historian, because some of his history was not quite accurate. I cannot agree that the first Factory Act applied particularly to women. It only

applied to those poor parish apprentices who filled our workhouses at that time, and whom both the works and the managers in Lancashire had the very good judgment to transfer from the workhouse to the factory. And again I cannot altogether agree with him that employers are always favourable to the Factory Acts. Even with the Act of 1831 the woollen manufacturers of Yorkshire fought so hard that they were able to prevent its application in their mills. The swing over to the wish for Factory Acts did not emanate from the owners in their desire to safeguard the workers, but for the benefit of education. The factory inspectors first of all as well as being factory inspectors were the first Government Inspectors of Schools, and they had to introduce schools wherever there were none. The effect of this on the morals and behaviour of the Lancashire children became so marked that the rest of the country followed suit and about 1850 we had the employers of Birmingham informing the Home Secretary that their works would be subject to the Factory Acts for the sake of the education of their children.

I agree with Mr. Southwell that our great changes came about the years of the war, and I would add one reason to the many he gave you as to why that change came about during wartime, and it is this. From the war onwards there has been, both on the directorate and the management side, a much better type of man running industry, and as far as managers are concerned, if I may say so in all sincerity, this fact is exemplified by the members of your own Institution. These men are coming up now with a broader education and a wider social outlook, and they are seeing things from a very different point of view than they saw them thirty years ago, in the old factories.

My second criticism is with regard to Section 13. Mr. Southwell said it was a new Section, but I am afraid it is only our old friend Section 10 dressed up in a new garb, I would like to say that this new Act relieves you of some of the disabilities of Section 10, or rather the case law that was built up round Section 10.

As regards lighting I have nothing to say except in admiration of what he has said, save to tell you that the committee of which our chief inspector was chairman has now issued a report, and all I have time to say to-night is that I would advise you to read it. Mr. Southwell's points on electrical matters are all excellent. The fact that he now runs his portable tools at 110 and his portable local lighting at 25 volts shows what can be done.

There is one point Mr. Southwell did not deal with, and I think I know the reason why, and that was the training of young persons which does not trouble him very much ; but I would ask you to look at this section of the Act, because the training of young persons needs much more attention. It is not due to callousness : it is due to your foreman knowing so much about their work—I have told

this tale very often but it will bear repeating. I remember going to see an accident where a boy had lost his finger oiling a gas engine. It was the first day he had been in the works. I met the manager and he swore that it was the boy's own fault, and then I saw the foreman who reiterated this. The third man I met was the man in charge who happened to be the boy's father, and he said in much stronger language than the others that it was definitely the boy's own fault. Then I asked which of the three men had shown the boy how to oil an engine, and there was a sudden silence. It was not callousness, but these three men knew so much about a gas engine that they did not think a man existed in this world who did not know how to do it. It was the boy's first day in the factory and he had never seen an engine in his life before. You will all realise that a man or boy new to the job should have very careful instructions as to the use of these machines, because they have probably never seen a machine in their lives before.

I am very much in agreement with Mr. Southwell's strong point that safety should begin in your designing department. It cannot be thought out after you get into the factory. That is one of the weaknesses in my friend Mr. Clarke's argument. I think you should therefore try and think that out, because the design will help you in everything, and it will help you to make your safety efforts so much more effective and at so much less cost.

Now I come to the question of power presses and I only wish to touch on this very shortly. There was one word in Mr. Southwell's paper that I did not quite agree with. He said the Home Office were getting impatient. I think what he should have said was "dissatisfied with the results." I find from the records that we have been at the question of heavy power presses for twelve years now : but apart from that I want to mention that the Home Office is now determined to get these things done. Mr. Southwell is a very valuable member of the committee which is considering these questions, and I think before long we will be able to give you results.

A point I want to raise with Mr. Southwell is this. I want to use that heavy power press as an illustration of the methods we are adopting. I do not wish you to think that there is sitting in Whitehall some impersonal being who with a very slight knowledge of the matter in hand throws regulations at industry and expects them to be carried out. There is nothing of the sort. What we are doing is to get together a band of qualified men out of the industry concerned. We take a little bit at a time, for example, the heavy power press, and we do get results. I might mention some achieved during the last few years, such as the flour milling machinery, bore ramming machinery, cable machinery, and hydraulic moulding and presses : and the marvel to me is that men such as Mr. Southwell are able and

willing to come forward without fee or reward and give us their time, their energy, their practical experience, and their technical ability, and help us over these matters.

Now that is what brings me up against Mr. Clarke. We would be only too pleased to sit back and let him produce a code of regulations. But when he talks of making small power presses safe he is also up against the law of the land. I am afraid he is not allowed to use them unless they are safe, but we will welcome any help that may come from this Institution or Mr. Clarke himself, and with that the only other thing I would suggest to-night is that if the Institution could do anything let it be constructive criticism that we can take in hand and that can be applied in the law of the land.

MR. CHAMBERS proposed a vote of thanks to Mr. Southwell for his lecture.